BPM System Requirements

RF Frequencies:

- 4 x 2.5MHz bunches (σ_t = 25 to 50 nsec)
- 12 x 7.5MHz bunches (σ_t = 6 to 12 nsec)
- Barrier buckets with debunched beam

Dynamic range: To be able to measure from 0.3E10 to 100E10 particles (injected beam) and 1 to 400E10 particles (stored beam).

Run Scenarios/Operations Modes: Protons and Pbars)

- **2.5 MHz**: In this mode of operation Main Injector completes a bucket to bucket transfer of 4 coalesced (2.5 Mhz) bunches spaced trwenty-one 53 Mhz buckets apart into the Recycler. The Recycler captures the beam in 2.5 Mhz buckets spaced twenty-one 53 Mhz buckets apart.
- **7.5 MHz**: In this mode of operation Main Injector completes a bucket to bucket transfer of 4 coalesced (2.5 Mhz) bunches spaced twenty-one 53 Mhz buckets apart into the Recycler. The Recycler captures the beam in barrier buckets, debunches the beam and rebunches the beam in 7.5 MHz for injection into the Tevatron for the 132ns spacing seneario.
- **89 KHz debunched beam in barrier buckets**: Barrier buckets in the Recycler are typically 40 buckets wide (53 Mhz buckets) and can have separations from 20 to 504 buckets with varying intensity listed in the Dynamic Range. Measurement would have a few hundred hertz bandwidth and represent the average position over a thousand turns.

Measurement Error Budget for bunched beam:

For less than 1E10 particles or greater than 10mm amplitude:

- 1.5mm RMS in absolute position
- 0.5mm RMS resolution/reproducibility – subsequent measurements on the same beam

For greater than 10E10 particles and less than 10mm amplitude:

- 0.5mm RMS in absolute position
- 0.15mm RMS resolution/reproducibility – subsequent measurements on the same beam

These performance specifications must be stable from day to day (with automatic calibration procedure if needed). We need to be able to close the Recycler injection orbit to the closed orbit to less than 0.25mm oscillation. We also need timing, global, house and BPM delay and calibration procedures to be documented and provided to MI staff.

Software Requirements:
The BPM package must provide real time data acquisition modes, operation mode coordination, and data scaling and access methods. The real-time component of this package implements the five required operational modes:

1. Flash Mode: Single turn position of beam orbit around the ring. We specifically need to be able to measure the first turn beam orbit in the Recycler after injection to the same accuracy as later orbits.
2. Background Flash Mode: Flash data taken at 720Hz.
3. Closed Orbit Mode: Average of up to 128 background flashes.
4. Turn by Turn Mode: Flash data for up to 1024 consecutive turns.
5. Turn by Turn scan Mode: Pinging and scanning diagnostics for the turn by turn mode.

Triggering Capabilities:
Each of the above modes of operation should have the following triggering capabilities:

- **Azimuthal delay** encoded with in a MDAT signal setting the global delay. This MDAT marks the start point of the different segments of beam within the Recycler to a 53 Mhz resolution.
- **Start event** specifies the RRBS event to be used to start the data acquisition mode
- **Turn Number** specifies the turn number to be collected
- **Number Turns** specifies the number of turns to average over
- **BeginTurnNum** specifies which turn to start acquiring data on
- **HorzChannel** specifies which of the horz channel data will be acquired on a given house
- **VertChannel** specifies which of the vert channel data will be acquired on a given house
- **Ping event** specifies RRBS event that will be used as the start trigger for a given channel
- **Ping spacing** specifies the time between ping events

Details for Operational Modes:

1. **Flash (**Azimuthal delay, Start event, turn number)
    - Start RRBS trigger event "start event"
    - Acquire on RRBS 0xC0 revolution marker (plus Azimuthal delay)
    - Store single turn data for "turn number"
    - 100 element history buffer
    - Not for the 89KHz mode

2. **Background Flash:** Azimuthal delay
    - Start asynchronously
    - Acquire on RRBS 0xC0 revolution marker (plus Azimuthal delay)

- Update single turn data sample MDAT synchronous at 720 Hz
- No history buffer
- Not for the 89KHz mode

3. **Closed Orbit (**Azimuthal delay, number turns)
    - Start on first 720 Hz MDAT message after 0xDA RRBS event
    - Acquire on RRBS 0xC0 revolution marker (plus Azimuthal delay)
    - Average "number turns" data sample MDAT synchronous to 720 Hz
    - 100 element history buffer

4. **Turn By Turn (**Azimuthal delay, Start event, Begin turn, number turns, Horz channel, Vert channel)
    - Start RRBS trigger event "start event"
    - Acquire on RRBS 0xC0 revolution marker (plus Azimuthal delay)
    - Store "number turns" consecutive turns starting at turn "Begin Turn"
    - 100 element history buffer
    - Not for the 89KHz mode

5. **Turn By Turn Scan (**Azimuthal delay, Start event, ping event, ping spacing, Begin turn, number turns)
    - Start RRBS trigger event "start event"
    - Acquire on RRBS 0xC0 revolution marker (plus Azimuthal delay)
    - Store "number turns" consecutive turns starting at turn "Begin Turn"
    - Not for the 89KHz mode